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AREAS OF HURRICANE DEVELOPMENT

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The phrase "area of development" with respect to hurricane formation needs further definition. Obviously this area is not a point, yet the concept is meaningless if it is expanded to encompass the entire known existence of the wave prior to the attainment of hurricane intensity. Namias and C. Dunn [3] in discussing the formation of hurricane Connie (1955) state: "While hurricane Connie was first reported on August 4 at about 16.6°N. and 48.0° W., there is some indication that it developed off North Africa some time earlier." Connie was scouted thoroughly by hurricane reconnaissance planes and it is quite definite that it did not reach hurricane intensity until more than 1,700 miles west of the Cape Verdes. And Connie continued to develop in intensity for another 700 miles or more. Just where should it be said that this hurricane developed?

The hurricane tracks of Mitchell [1] and Tannehill [2] apparently were constructed by tracing each storm as far back as any evidence of circulation or strong winds could be found, although the criteria used by them are not fully described. In some cases the track apparently begins where a full-fledged hurricane was discovered and in others where ship reports merely indicated the existence of an unstable wave with mildly squally weather or somewhat abnormal winds.

It is not the purpose of this paper to define "area of development". However there is an arbitrary point in the development—where the tropical storm reaches hurricane intensity—that can be located within a reasonable degree of accuracy. It is believed this particular hurricane statistic may be of some value.

All hurricanes from 1901 to 1955 have been studied and the location where they attained hurricane intensity plotted, if sufficient information permitted reasonable accuracy. Considerable reliance has been placed on articles and other information appearing in the *Monthly Weather Review* during this period. With plane reconnaissance during the past decade, positions can usually be estimated very closely. Many tropical storms are first encountered by ships on the New York to Capetown route and frequently several ships may send in reports on the day of discovery. Inferences can be made from the lowest pressure, wind velocities, and wind shifts concerning the maturity and intensity of the storm and consequently the probable position where it reached hurricane intensity. In the area west of long. 60° W., it is believed the point where the tropical storm reaches hurricane intensity can be located accurately, within 150 miles, approximately 85 percent of the time. The area of greatest uncertainty is southeast of Bermuda. East of long. 60° W., the positions become more questionable as the data become scarcer. In this area, the errors have a bias and in almost all cases the position, if in error, should be farther to the east than plotted. Hurricane positions during the first decade and a half are less reliable than positions since 1915.

Of the 242 hurricanes from 1901–55 used in this study, approximately 40 developed in perturbations moving away from the intertropical convergence zone (ITC) in the Panama region, although almost all of the major developments occurred a considerable distance away from the ITC. Most of the remaining hurricanes (202) developed in easterly waves. The origin of easterly waves is obscure but some develop as a result of a fracture of polar troughs and many others enter our field of observations, which here in Miami begins in the vicinity of the Cape Verde Islands, from the east. It is evident that the great majority of the Atlantic hurricanes do not develop in the "doldrums",

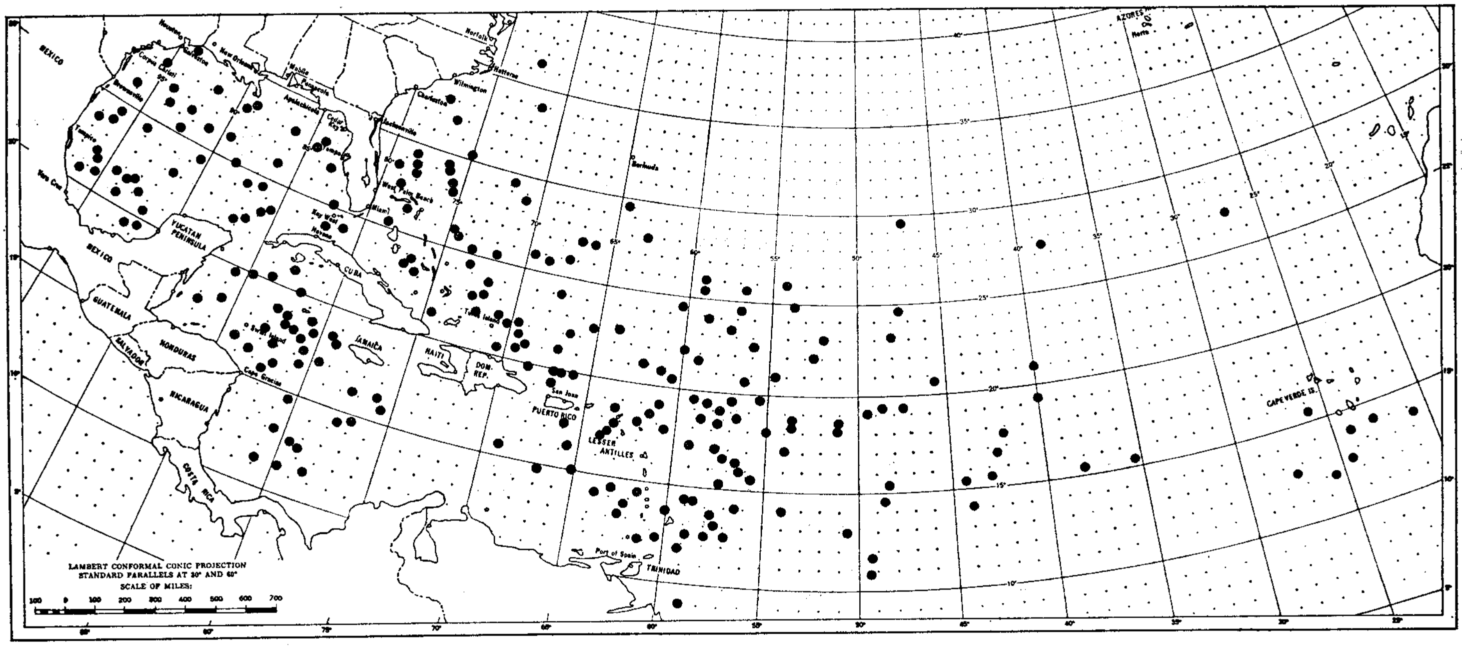

Figure 1.—Locations where tropical storms reached hurricane intensity, 1901–55.

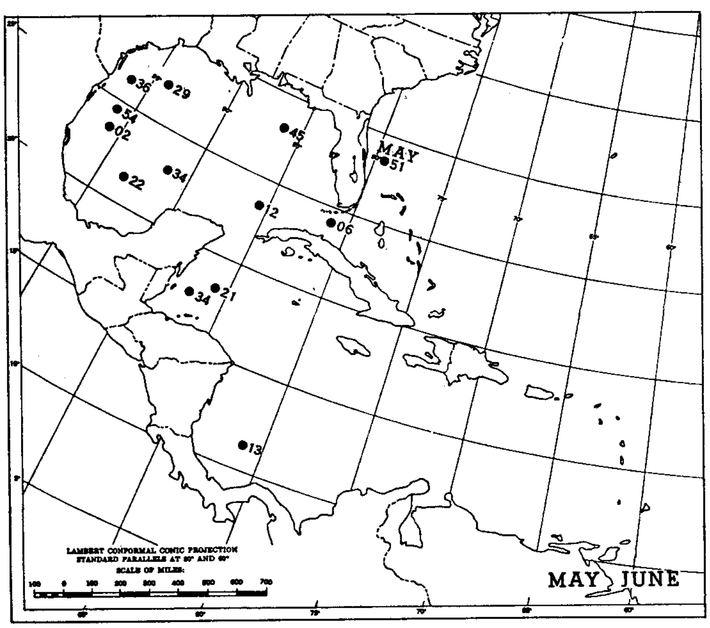

Figure 2.—Locations where tropical storms reached hurricane intensity, May and June, 1901–55. The two-digit number at each location indicates the year.

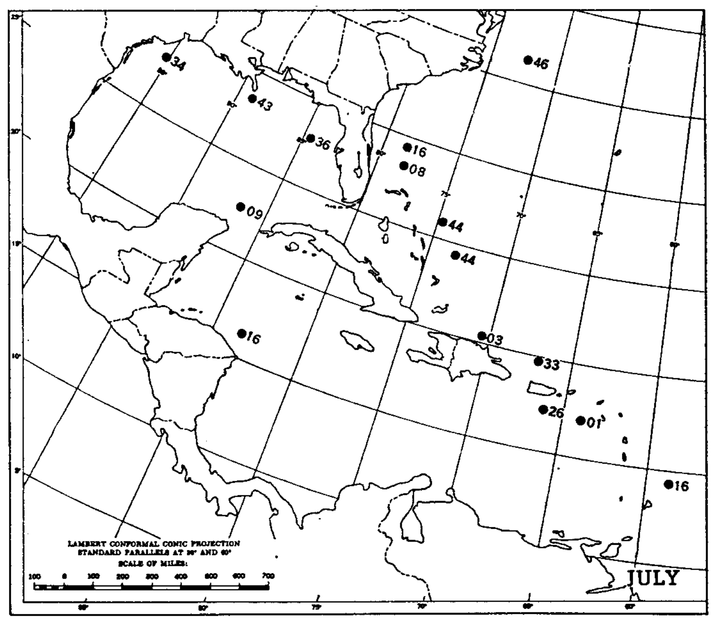

Figure 3.—Locations where tropical storms reached hurricane intensity, July, 1901–55. The two-digit number at each location indicates the year.

which to many of the earlier authors was synonymous with what is now termed the ITC, but rather in the trade wind current. Indeed a comparison of the areas of hurricane formation in the Atlantic with the Atlas of Climatic Charts of the Ocean [4] would indicate many of the tropical storms undergo their major and most rapid development in the region where the constancy and strength of the trades is the greatest and frequency of calms the least (fig. 4).

In the comparatively few cases where tropical storms reach full hurricane intensity in or near the ITC, development usually takes place slowly, sometimes requiring as long as 6 days from the time the wave can be described as unstable until it reaches hurricane intensity. On the other hand, intensification in easterly waves is more rapid, perhaps averaging about 3 days.

The positions where all 242 of the tropical cyclones are estimated or known to have reached hurricane intensity are plotted in figure 1. A concentration just to the east of Swan Island and another just to the east of the Leeward and Windward Islands can be noted. The only 5° squares west of long. 35° W. where none developed are the two between western Hispaniola and Venezuela. Mitchell [1]

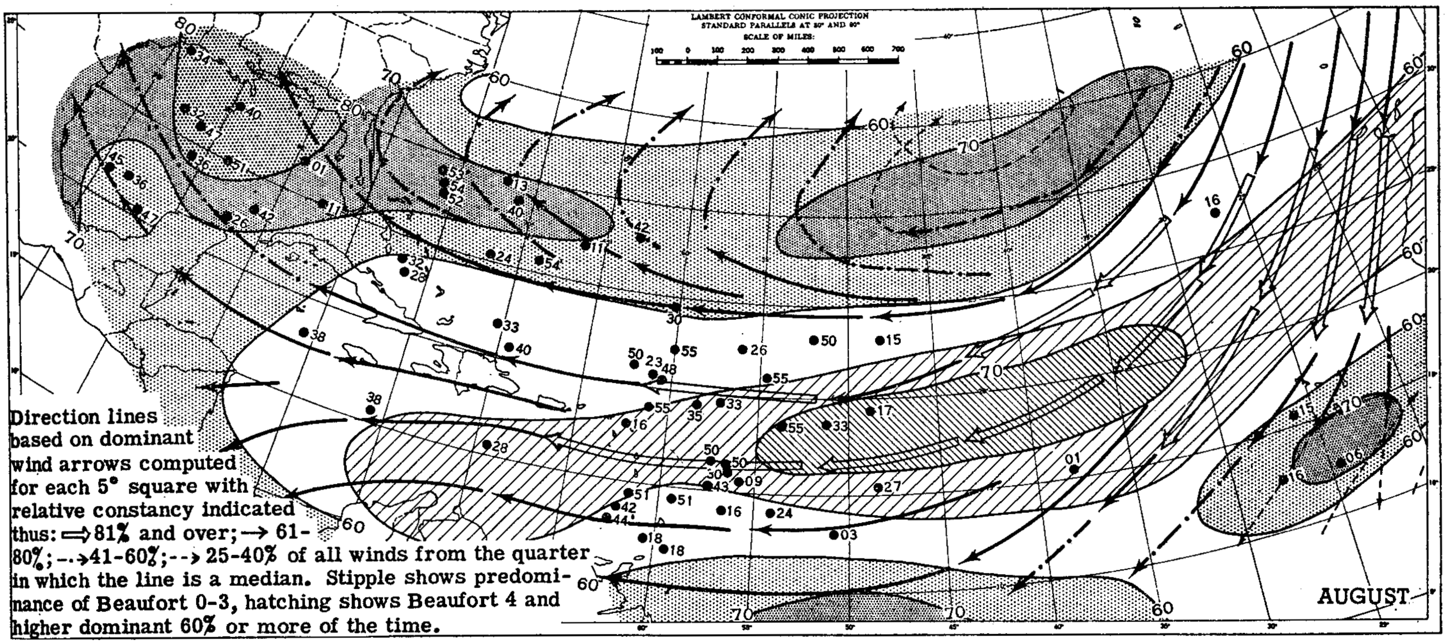

Figure 4.—Locations where tropical storms reached hurricane intensity, August 1901–55. The two digit number at each location indicates the year. Predominant wind direction and constancy are indicated by the arrows and predominant wind force by the stippling (see explanation inset on chart).

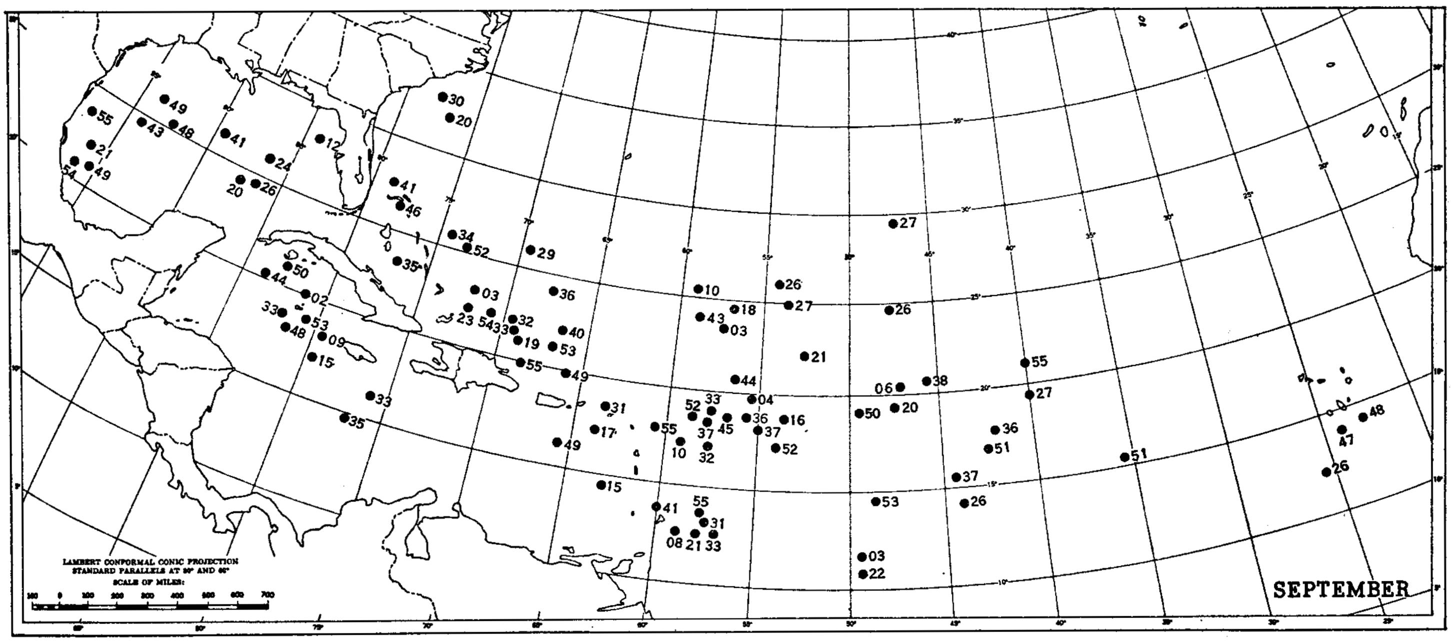

Figure 5.—Locations where tropical storms reached hurricane intensity, September, 1901–55. The two-digit number at each location indicates the year.

stated, "In every instance the *first evidence* of storm development, although rather obscure in some cases, was found either over the western third of the Caribbean Sea (west of long. 78° W.) or to the east of the eastern limits of the Caribbean Sea." This statement has been misquoted by others to the effect that hurricanes do not develop in the eastern and central portions of the Caribbean. Certainly comparatively few storms reach hurricane intensity in this area, particularly between longitudes 67° and 75°, perhaps due to the significant divergence in the lower tropospheric easterly flow as the easterly trade is diverted into the heat Low over the Amazon Valley. On the other hand, two recent severe hurricanes—Hazel 1954 and Janet 1955—attained great intensity in this area although both were comparatively weak hurricanes when they entered the Caribbean.

Seven hurricane developments have been placed in the Cape Verde area. These positions are largely based on the works of earlier investigators. In the majority of cases the evidence available to the author, indicated only that

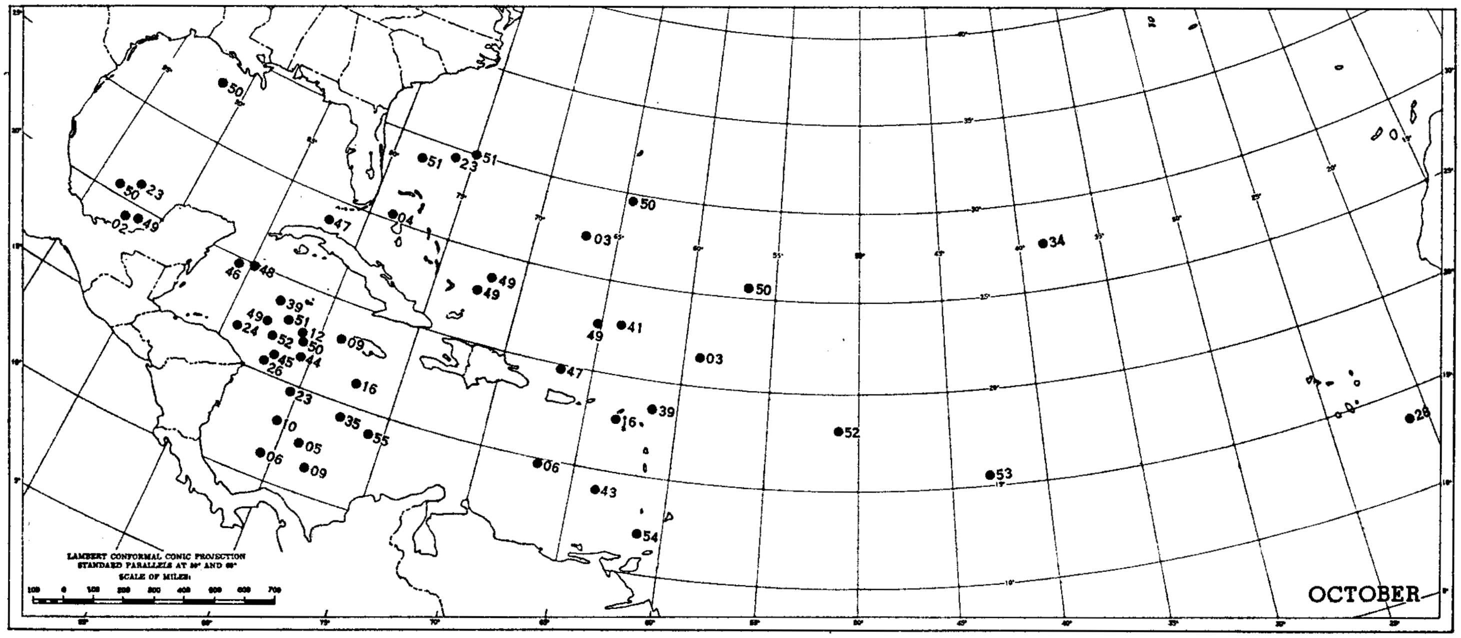

FIGURE 6.—Locations where tropical storms reached hurricane intensity, October, 1901–55. The two-digit number at each location indicates the year.

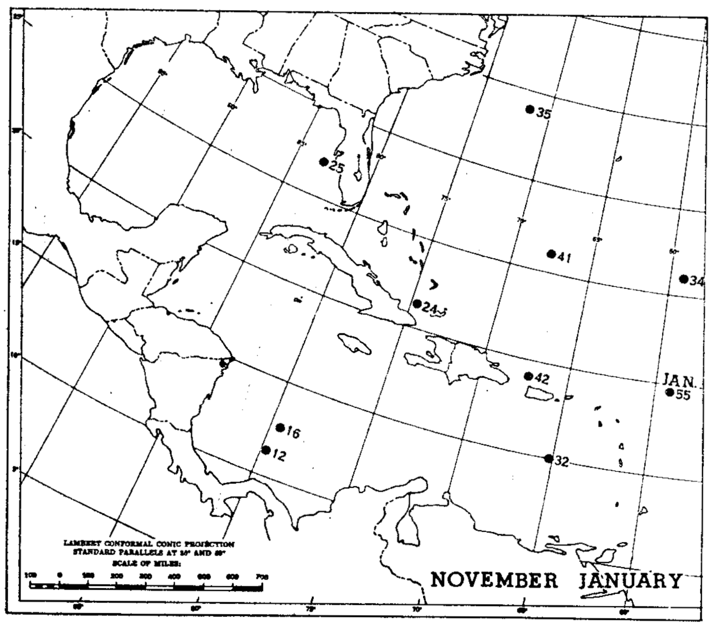

FIGURE 7.—Locations where tropical storms reached hurricane intensity, November and January, 1901–55. The two-digit number at each location indicates the year.

an unstable wave passed through the islands and that the hurricane intensity was actually reached some 10° to 15° to the westward.

The only May hurricane developed off the east coast of Florida (fig. 2). Hurricane formation in June (13 storms) (fig. 2) is confined to the extreme western Caribbean and Gulf of Mexico, as is well known.

July hurricane positions are plotted on figure 3. Nine of the 15 reached hurricane intensity along a narrow band from northeast of Barbados northwestward to a point off the Florida east coast. One in 1946 reached hurricane intensity in about lat. 36.5° N. and long. 72.5° W., the northernmost position noted during this period. Four hurricanes formed in the Gulf of Mexico, one in the northwestern Caribbean and none east of long. 58° W.

The 64 hurricanes in August (fig. 4) are well scattered between lat. 11° and 30° N. in the Atlantic and Gulf of Mexico with the greatest concentration in and east of the Leeward and Windward Islands. Only 3 August hurricanes formed in the Caribbean Sea west of long. 62.5° W. and 2 of these 3 were in 1938. On figure 4, the predominant wind direction, constancy, and force from the Climatic Atlas [4] have been superimposed on the hurricane development chart. It will be noted that only three tropical storms reached hurricane intensity near the ITC in the vicinity of the Cape Verdes. All three were in 1916 or earlier. Squalls of hurricane force were reported in connection with one storm in the area but it is quite possible the other two reached hurricane intensity farther to the westward. The heavy concentration in and east of the eastern Antilles, it can be seen, lies astride the trade wind current of greatest constancy and strength.

September's 90 hurricanes (fig. 5) are spaced rather similarly to August's except for a significant number forming in the northwestern Caribbean Sea and close to the Mexican coast in the Gulf of Mexico.

The principal concentration in October, figure 6, is in the northwestern Caribbean with marked diminution in all other sections. Formation in the Gulf of Mexico was largely confined to the Bay of Campeche.

The nine storms in November and the one in January developed between long. 59° and 80° W. except for the one off the southwest coast of Florida in late November in 1925 (fig. 7). These late season storms are few and unimportant.

REFERENCES

1. C. L. Mitchell, "West Indian Hurricanes and Other Tropical Cyclones of the North Atlantic Ocean", *Monthly Weather Review, Supplement* No. 24, Washington, D. C., 1924, 47 pp.
2. I. R. Tannehill, *Hurricanes*, Princeton University Press, 1945.
3. J. Namias and C. R. Dunn. "The Weather and Circulation of August 1955—Including the Climatological Background for Hurricanes Connie and Diane", *Monthly Weather Review*, vol. 83, No. 8, August 1955, pp. 163–170. (See p. 164.)
4. U. S. Weather Bureau, *Atlas of Climatic Charts of the Oceans*, Washington, D. C., 1938.

WEATHER NOTES

A NEW ONE-MINUTE RAINFALL RECORD

Introduction.—During the early morning hours of July 10, 1955, heavy thunderstorm activity occurred over an area embracing several counties just west of the center of Iowa. Associated with one of these storms there was a particularly heavy burst of rain that established a new United States record and possibly a new world's record for the heaviest recorded 1-minute rainfall. Over a period of 1.4 minutes the rate of fall was 0.69 inch per minute. For some shorter periods the rate was considerably greater.

At Opid's Camp, Calif., a storm on April 5, 1926, produced heavy rain that has been evaluated at 0.65 inch per minute [1]. A rainfall of 0.82 inch per minute was reported from Porto Bello, Panama, on November 29, 1911, but the nature of the record leaves considerable doubt about its reliability [2]. Other heavy rainfall records for various periods are listed in reference [3].

The new record rainfall was collected in a 9-inch, single-traverse, unshielded, Universal recording gage that was the property of the U. S. Weather Bureau, but on loan to the Iowa Natural Resources Council. Mr. Lawrence Nahnsen, on whose farm the gage was located, was serving as rainfall observer and operator of the gage for the Resources Council. The farm is 11 miles north of the town of Jefferson, in Greene County, Iowa.

The exposure of the gage is good. A few trees are located about 80 feet north of the gage. Shrubs to the west and south of the gage are at a distance of 32 feet and 24 feet, respectively. The house is 100 feet or more away, in a northwesterly direction, and the barn is even farther removed to the east.

The U. S. Geological Survey has a recording stream gage and sediment measuring station about 5 miles downstream on the East Fork of Hardin Creek, which drains the area over which the heavy rain fell. That agency obtained a very interesting trace of the stream rise associated with this storm.

Evaluation of the Record.—The chart had been on the drum for a period of nearly 10 days before the heavy rainfall was recorded. It was some time after the storm before the heavy rate of fall came to our attention, and by that time it was not possible to reconstruct some of the details relating to the storm. A study of the trace indicates that the clock was running at the time of the heavy rain, although the drum did not appear to be set to the correct time.

From interviews with the observer, and with others living in the vicinity, it appears that the heaviest rain probably fell around 2 or 3 a. m. The trace ends about an hour and a half after the storm. This would suggest that probably the clock had stopped before the chart was changed.

A study of the chart indicates that rain was still falling at an excessive rate at the time the pen was lifted off the chart by the clip holding the chart on the drum. The pen line reappeared on the other side of the clip some 20 minutes later and 0.29 inch higher. At the time the line was lost on the clip, the trace was approaching the clip at an angle of about 11°, showing that the drum was turning. There was nothing in the trace to indicate that the drum movement was restricted as a result of contact of the pen with the clip. The trace developed on previous days, when there had been no precipitation, indicates that the chart was properly mounted on the drum, with the edge uniformly against the flange.

The precise evaluation of so small a record chart with such a steep trace is difficult, and there is a strong probability that there is some error in the values developed by this study. However, every possible precaution has been taken to avoid misinterpretation and to keep the errors of measurement and computation as small as possible.

In order to obtain sufficient enlargement to permit careful study of the record, a Kodachrome slide was prepared of that part of the chart that was of particular interest. (Figure 1 is an enlargement from the slide.) The image of the slide was then projected onto a large sheet of stiff paper that was firmly fastened to the wall at the end of a long hall. On the enlargement the time scale measured 0.43 inch per minute, and the precipitation scale was 35.44 inches per inch of rain. A sharp line was traced through the middle of each appropriate line on the projected image, being particularly careful to follow any minor variations that were apparent in the trace.

A calibration of the gage shortly after the record was established indicated that 1.00 inch of precipitation in the range involved showed an increment of 1.01 inch on the chart. Therefore, a measurement of the ordinate distance of 1.01 inches of rain (35.80 inches) was divided by 100 to obtain the proper spacing for the 0.01 intervals, and rainfall amounts were measured on this basis.

The distances between 20-minute time arcs both prior to and following the heavy precipitation were averaged in computing the mean 1-minute distance, and a scale was prepared showing 0.10-minute intervals.

Readings of vertical and horizontal distance from the starting point were made on the large-scale tracing (to hundredths of an inch) for every 0.10 (corrected) inch of rainfall. Readings were also made, independently for every 0.10 minute (6 seconds). The two sets of readings were plotted on coordinate paper to check for consistency, and were found to agree very well. The measurements were then reduced to amounts and times (table 1).

A two-way table was then prepared showing, for each interval, the elapsed time and the increment of precipitation, as well as the rate of fall per minute for that interval. From this table, it was possible to determine readily the greatest rate of precipitation indicated for any given interval of time.

A plot of cumulative rainfall against time indicates that although heavy precipitation was continuous through the period in question there were two separate intervals during which rainfall was substantially heavier than it was during the rest of the time. Beginning at 0.10 minute after time zero and continuing for 0.20 minute rainfall was particularly heavy. The rate was less for nearly 1 minute, then beginning at 1.30 minutes after time zero another heavy burst occurred, which lasted until the record was terminated by the spring clip 0.20 minutes later. Any 60-second period which utilizes either of these intervals of heavier rainfall shows 0.67 inch per minute. By extending the time interval to 1.4 minutes, it is possible to include both of these periods in one computation to obtain an average rate of 0.69 inch per minute for a 1.4 minute period. Since this rate was maintained for longer than 1 minute, it has been adopted as the 1-minute record.

Synoptic Situation.—On the morning of July 10, a stationary front lay in an east-west line across northern Missouri. There was considerable shower and thunderstorm activity north of the front, and numerous reporting stations measured total rainfall of from 1 to 3 inches during the 48 hours of the 9th and 10th.

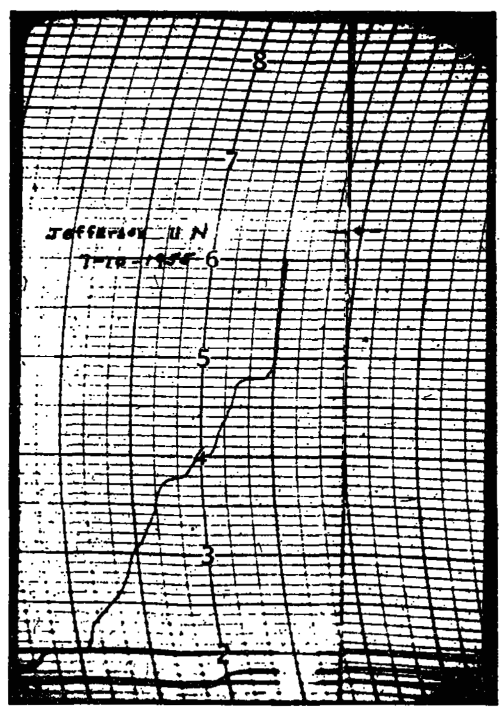

FIGURE 1.—Reproduction of hydrograph record during storm of July 10, 1955.